Trent University: PHYS 2700H – Thermal Physics 2025 – 2026

Final Exam: Saturday Apr 18, 2026 **Name:__________________**

Allowed: Formula sheet (given), calculator, 2 ½ hours

PART 1 – answer questions **1-7** in the exam booklet provided and **then** use your scratch card: One scratch = **100%**; two scratches **33%**; three scratches **25%** (part 1 total is 40%)

PART 2 – answer questions **8–10** in the exam booklet provided (each question here is worth 20%)

Qu's 1-2: Consider *n* moles of an ideal gas with adiabatic exponent γ, initially at P_i, V_i and T_i, which reversibly undergoes an adiabatic compression to P_f, V_f and T_f.

1) What is the final pressure of the gas, P_f, after this process in terms of the volume change?

A. $(V_f / V_i)^{\gamma-1} P_i$ **B.** $(V_i / V_f)^{\gamma-1} P_i$ **C.** $(V_i / V_f)^{\gamma} P_i$ **D.** $(V_f / V_i)^{\gamma} P_i$ **E.** $(V_i / V_f) P_i$

2) Which of the following equations correctly relates the final temperature and volume of the gas to its initial temperature and volume?

A. $T_f^{\gamma} V_f = T_i^{\gamma} V_i$ **B.** $T_f V_f^{\gamma-1} = T_i V_i^{\gamma-1}$ **C.** $T_f^{\gamma} V_f = T_i^{\gamma} V_i$ **D.** $T_f^{\gamma} V_f = T_i^{\gamma} V_i$ **E.** $T_f V_f^{\frac{\gamma-1}{\gamma}} = T_i V_i^{\frac{\gamma-1}{\gamma}}$

Qu's 3-4) Consider 3 moles of helium with initial volume and pressure of $V_1 = 64\ \text{dm}^3$ and $P_1 = 1\ \text{atm}$, respectively. We shall treat the helium as an ideal monatomic gas. The gas undergoes an *isobaric expansion* to twice its original volume.

3) Which of the following best represents the change in internal energy of the gas?

A. 6.0 kJ **B.** 7.3 kJ **C.** 8.8 kJ **D.** 9.7 kJ **E.** 4.7 kJ

4) Which of the following best represents the change in enthalpy of the gas?

A. 15.2 kJ **B.** 28.5 kJ **C.** 23.6 kJ **D.** 19.4 kJ **E.** 16.2 kJ

5) Suppose a fridge runs on 60 W of electrical power, while releasing 360 W of heat into the basement. Which of the following is the *coefficient of performance* of this fridge?

A. 14 **B.** 5 **C.** 0.86 **D.** 1.2 **E.** 0.17

Qu's 6–7: A fairly elementary calculation of the total number of ways to assign the N indistinguishable particles of an ideal monatomic gas with volume V and internal energy $U = N \times \frac{1}{2} m\overline{v^2}$ among the permitted cells of phase space gives $\left(\frac{eVp_{rms}^3}{Nh^3}\right)^N$, where e is Euler's number (2.718…) and *rms* denotes 'root mean square'.

6) Which of the following expressions is therefore the entropy of this gas, in terms of volume and temperature?

A. $S = Nk_B \ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{5/2}\right]$ **B.** $S = Nk_B \ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{5/2}\right]$ **C.** $S = nk_B \ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{3/2}\right]$

D. $S = Nk_B \ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{3/2}\right]$ **E.** $S = nR\ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^3}\right)^{5/2}\right]$

7) A more-advanced calculation results in the *Sacker-Tetrode expression* for the entropy of an ideal monatomic gas:

$$S = Nk_\mathrm{B} \ln\left[\frac{V}{N}\left(\frac{2\pi mk_BT}{h^2}\right)^{3/2}\right] + \frac{5}{2}Nk_\mathrm{B}$$

Using this expression, what is the entropy of one mole of ^{4}He at 293 K and 1 atm?

A. 92 J/K **B.** 104 J/K **C.** 115 J/K **D.** 126 J/K **E.** 146 J/K

PART II – answer all <u>three</u> questions in exam booklet provided

8. The equation of state for a stretched elastic band connects the tension F, the length L, and the temperature T according to:

$$F = aT\left[\frac{L}{L_0} - \left(\frac{L_0}{L}\right)^2\right] \quad ,$$

where L_0 is the unstretched length, T is in Kelvin, and a is a constant.
(a) Write down the cyclic relation between F, L, and T, and from this obtain an expression for $\left(\partial F / \partial T\right)_L$ in terms of two other partial derivatives.
(b) Make a large sketch of $F\left(L\right)$ showing L ranging from L_0 to $4L_0$ for **two** temperatures: T_1 and $\frac{9}{4}T_1$, and find for these two temperatures the values of F at $2L_0$ and $4L_0$.
(c) An elastic band follows a cycle, going from point **a** at $4L_0$ and T_1; directly to point **b** at $4L_0$ and $\frac{9}{4}T_1$; then isothermally to point **c** at $2L_0$; then directly back to **a**, etc. (Note that points **c** and **a** correspond to the same force). Label this cycle on your graph, and write down the integral in terms of a, L_0 and T_1 (but you do not need to compute it) for the work done **by** the elastic band in going from **b** to **c**.
(Note the infinitesimal work done *on* a stretched elastic band when it lengthens by dL is $\text{đ}W = FdL$).

9. (a) Explain the physical significance of the *a* and the *b* variables in the equation of state for a *van der Waals gas* and why these values are zero for an ideal gas.
(b) Sketch a *PV* diagram for a single substance that shows the regions corresponding to a vapour and a vapour-liquid mix. Label also the location of the *critical point*, C. Draw on this diagram isotherms for both an ideal gas and a van der Waal gas that pass slightly above the critical point, and explain the qualitative differences between the isotherms.
(c) The location of the critical point C can be found from the requirement that both the first and second derivative of $P\left(V\right)$ for the critical isotherm is zero: namely $\left(\partial P / \partial V\right)_{T_c} = 0$ and $\left(\partial^2 P / \partial V^2\right)_{T_c} = 0$.
Given this, find in terms of *a* and *b* the critical pressure and critical volume of a van der Waal gas.

10. Consider the Gibbs function, *G*, for a *closed* system.
(a) Determine from the appropriate thermodynamic identity an expression for the entropy and the volume of the system in terms of partial derivatives of *G*.
(b) Derive the corresponding Maxwell relation.
(c) How does the thermodynamic identity change if the system were instead *open*? Find an expression for the chemical potential of the system in terms of a partial derivative of *G*.
(d) If two open systems composed of the same single substance are free to exchange particles with each other, and system 1 has a chemical potential of $\mu_1 = -0.646\ \text{eV}$, while system 2 has a chemical potential of $\mu_2 = -0.346\ \text{eV}$, then which way, if at all, is there a net flow of particles?